



US007230374B2

(12) **United States Patent**
Suh et al.

(10) **Patent No.:** **US 7,230,374 B2**
(45) **Date of Patent:** **Jun. 12, 2007**

(54) **FULL COLOR ORGANIC LIGHT-EMITTING DEVICE HAVING COLOR MODULATION LAYER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/981,565**

(22) Filed: **Nov. 5, 2004**

(65) **Prior Publication Data**

US 2005/0093434 A1 May 5, 2005

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/914,119, filed on Aug. 10, 2004.

(30) **Foreign Application Priority Data**

Sep. 22, 2003 (KR) 2003-65683

(51) **Int. Cl.**
H05B 33/22 (2006.01)

(52) **U.S. Cl.** **313/504; 313/501**

(58) **Field of Classification Search** 313/498-512;
345/43, 45, 76, 92, 36; 427/68, 555; 428/690,
428/917, 913; 315/169.3

See application file for complete search history.

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Primary Examiner—Mariceli Santiago

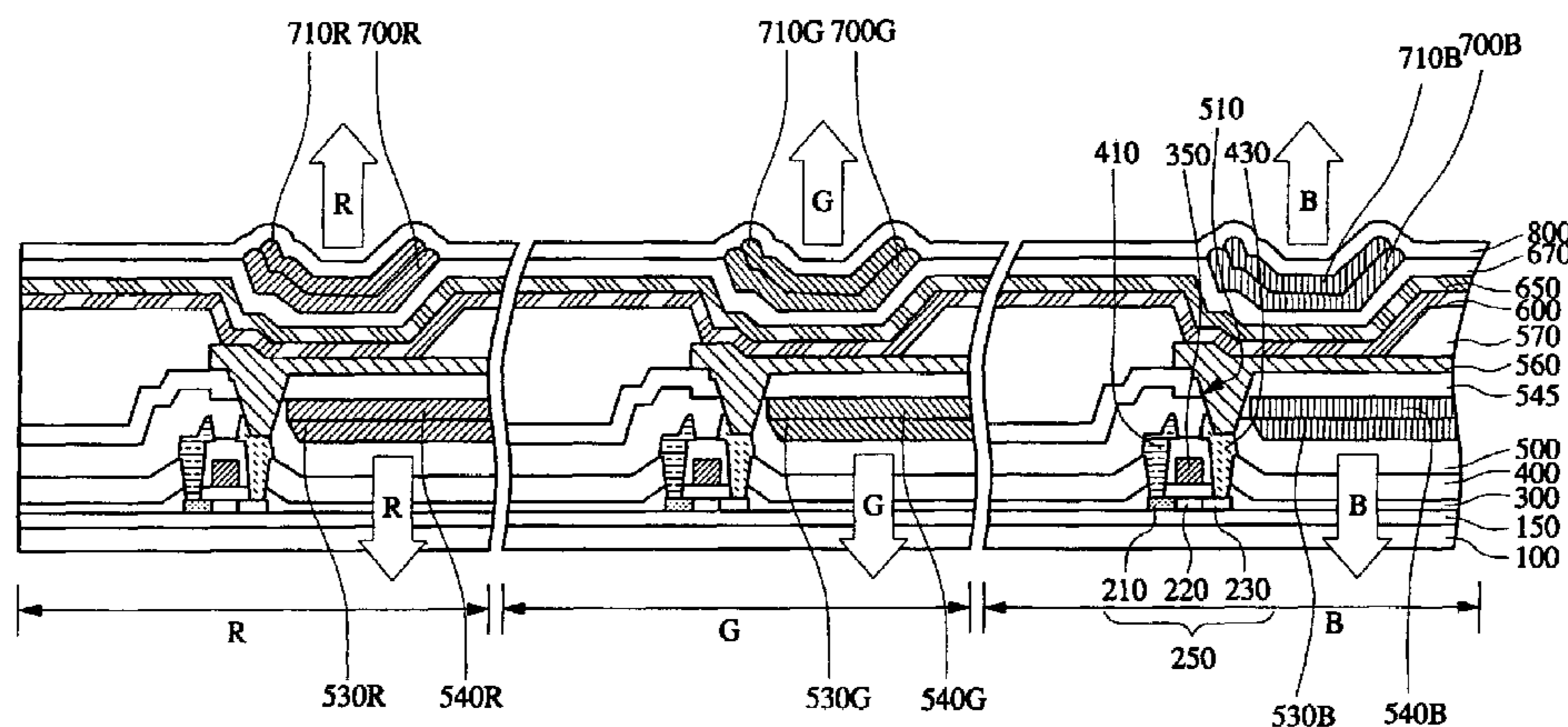
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(57) **ABSTRACT**

An organic light-emitting device has a color modulation layer. The organic light-emitting device comprises a substrate, a first electrode positioned on the substrate and a second electrode positioned on the first electrode, wherein at least one of the first electrode and the second electrode is transparent. An organic functional layer having at least an emission layer emitting white color light is interposed between the first electrode and the second electrode. A color modulation layer formed by a laser-induced thermal imaging method is positioned on a surface opposite to a surface adjacent to the emission layer of the transparent electrode, wherein the color modulation layer has at least a color conversion medium.

31 Claims, 9 Drawing Sheets



US 7,230,374 B2

Page 2

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FIG. 1

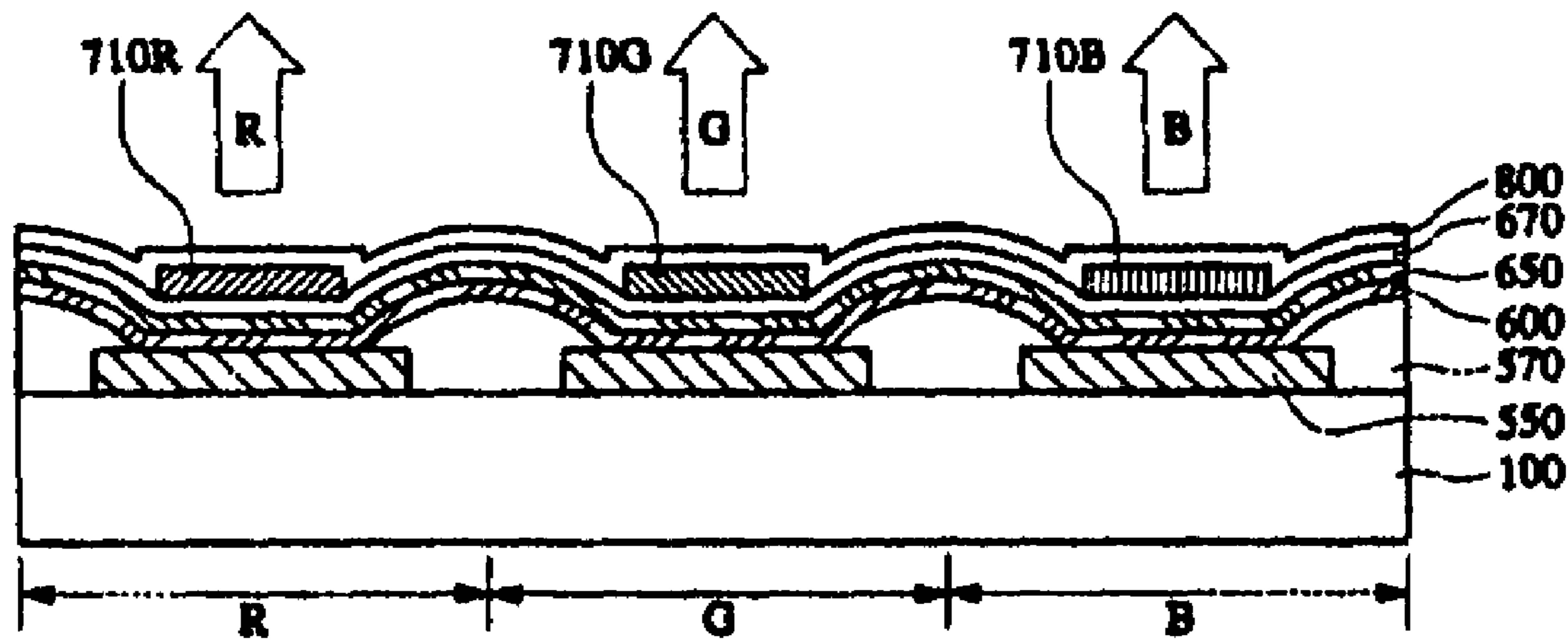


FIG. 2

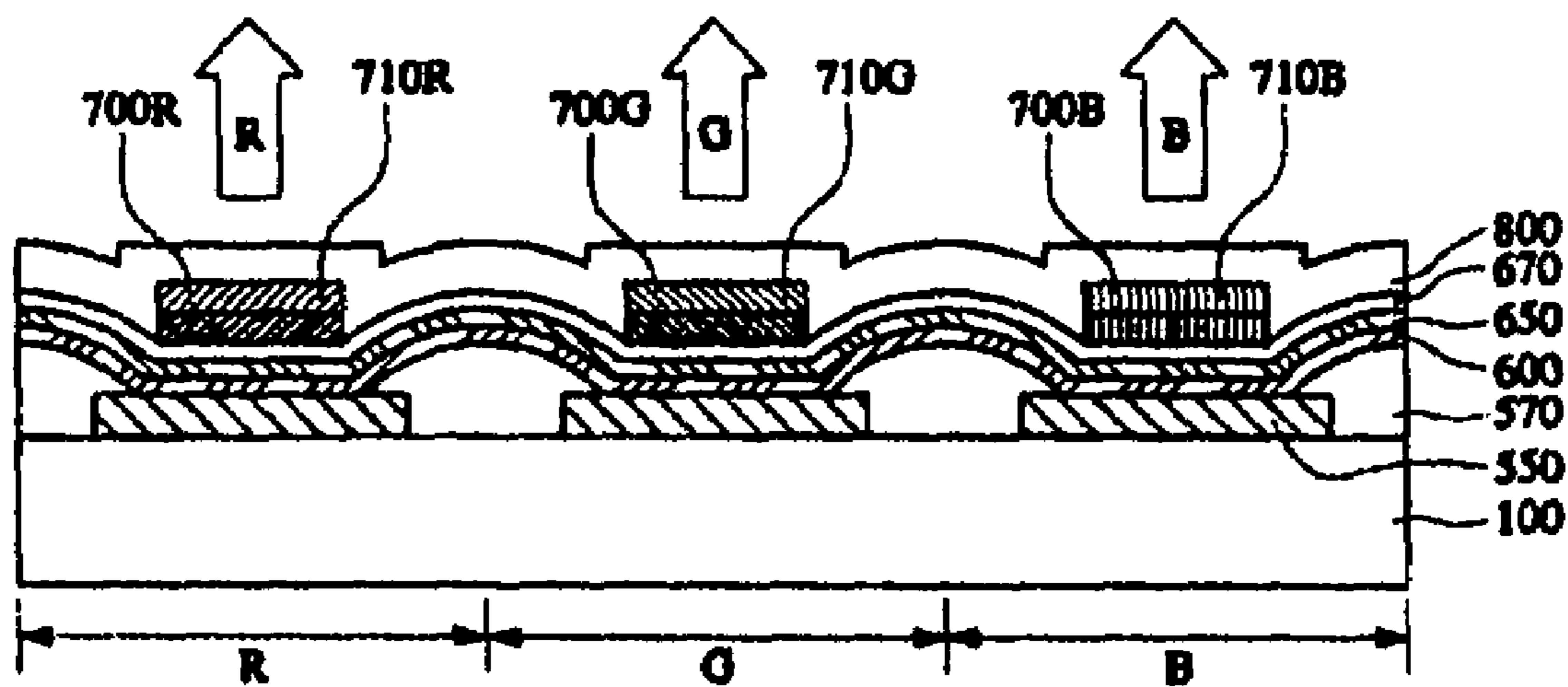


FIG. 3

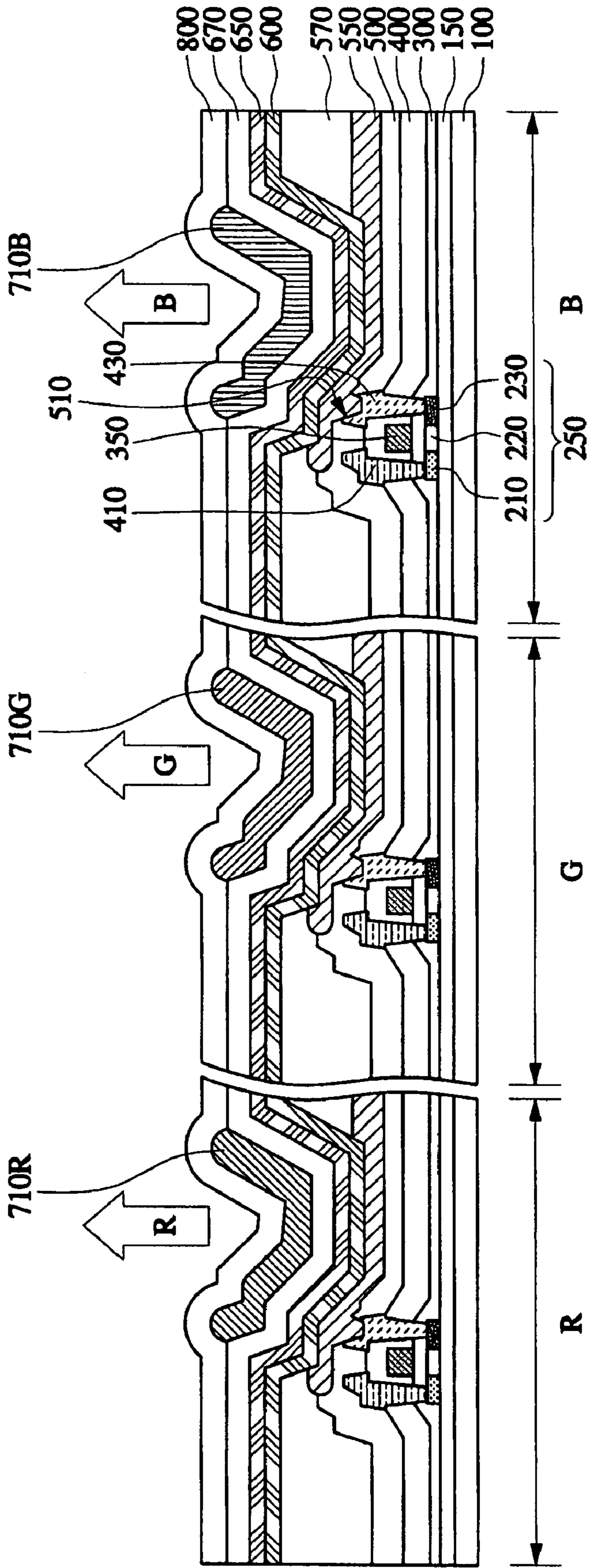


FIG. 4

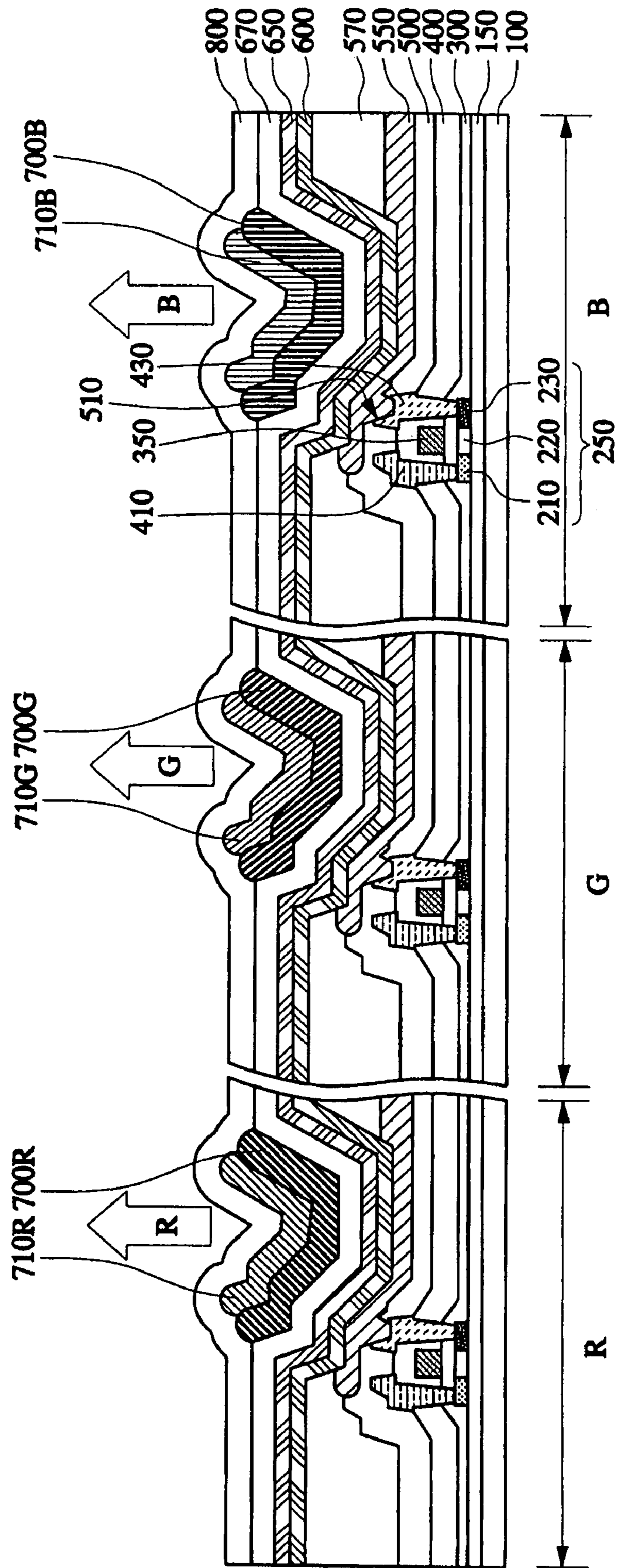


FIG. 5

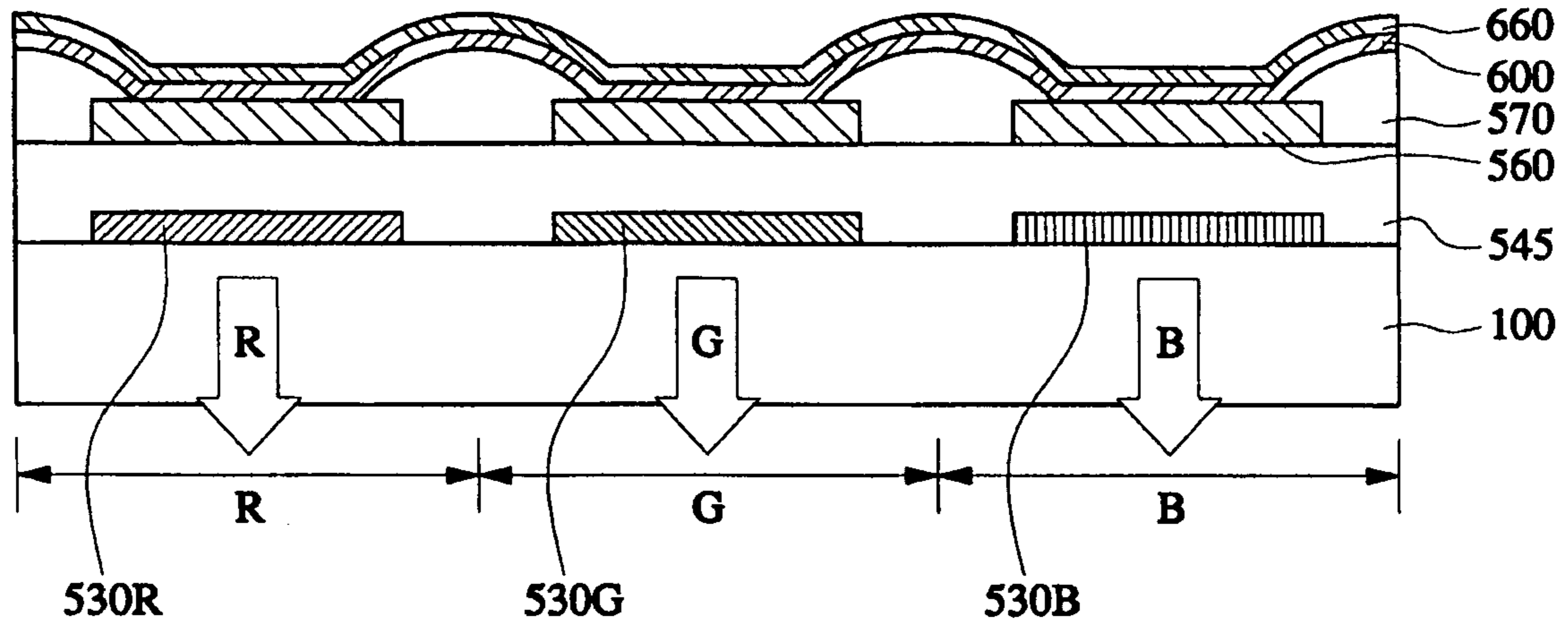


FIG. 6

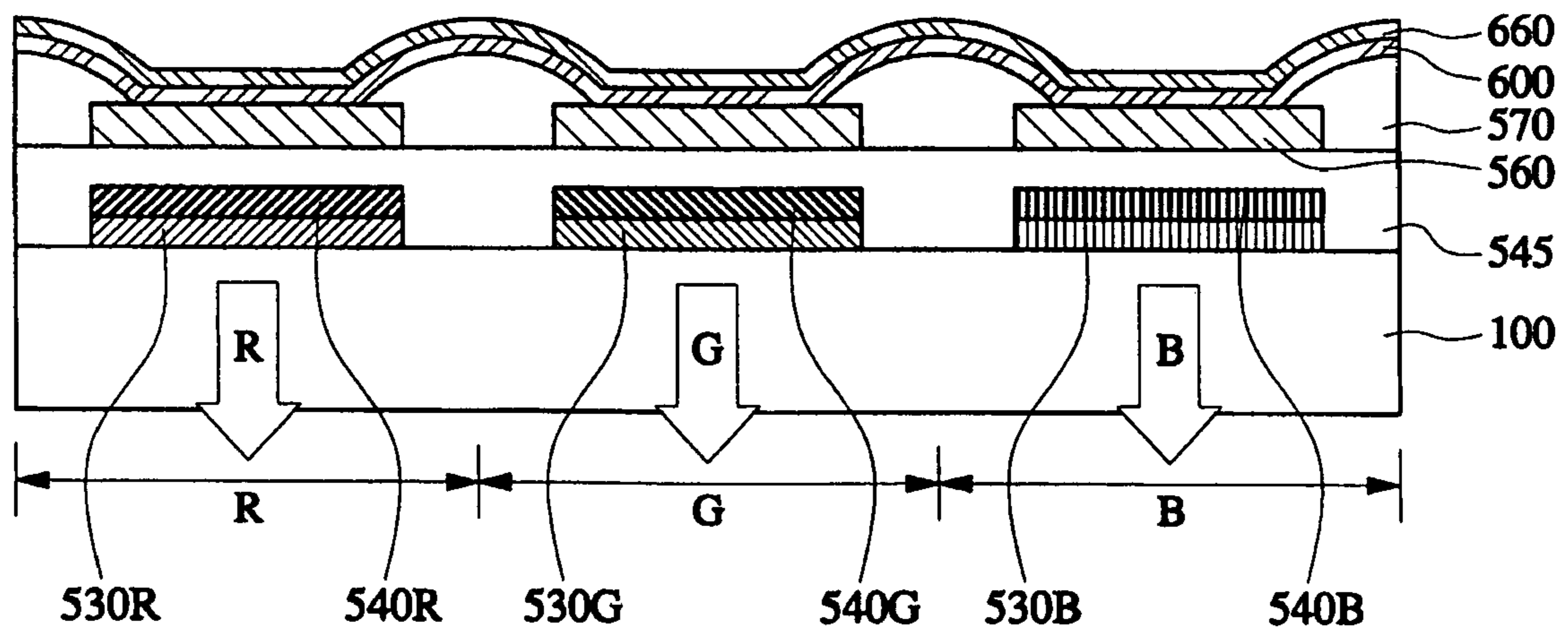


FIG. 7

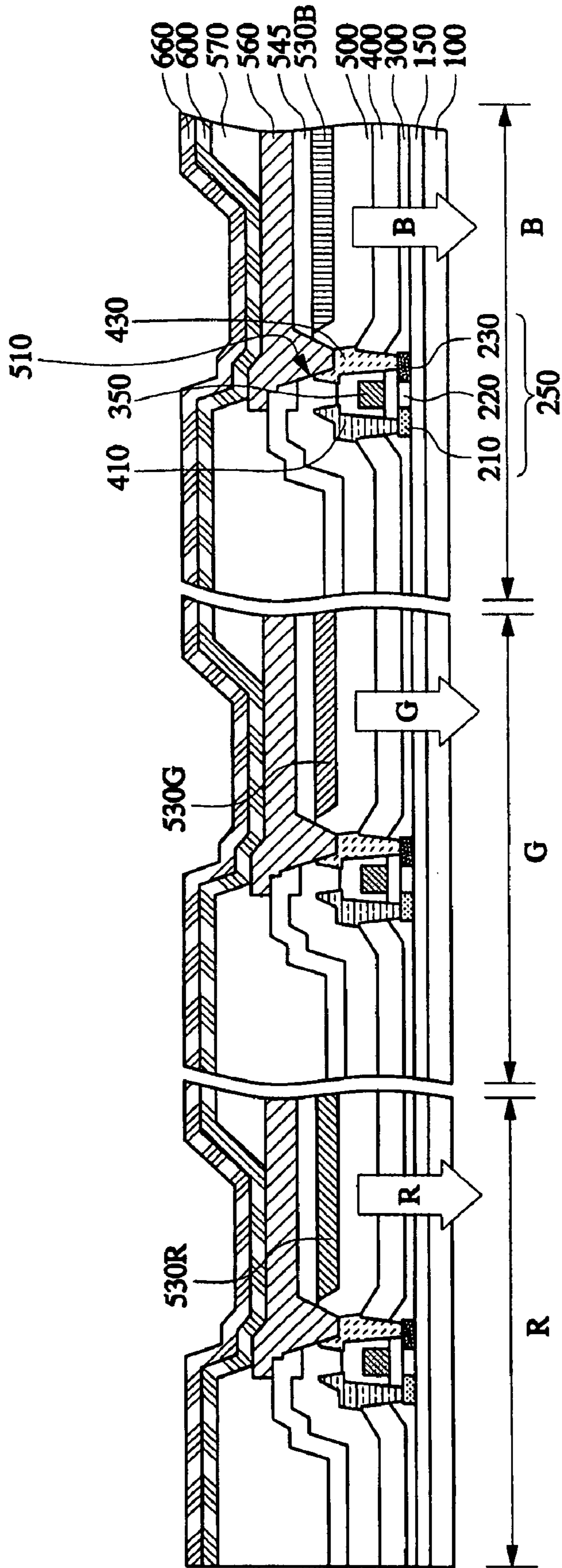


FIG. 8

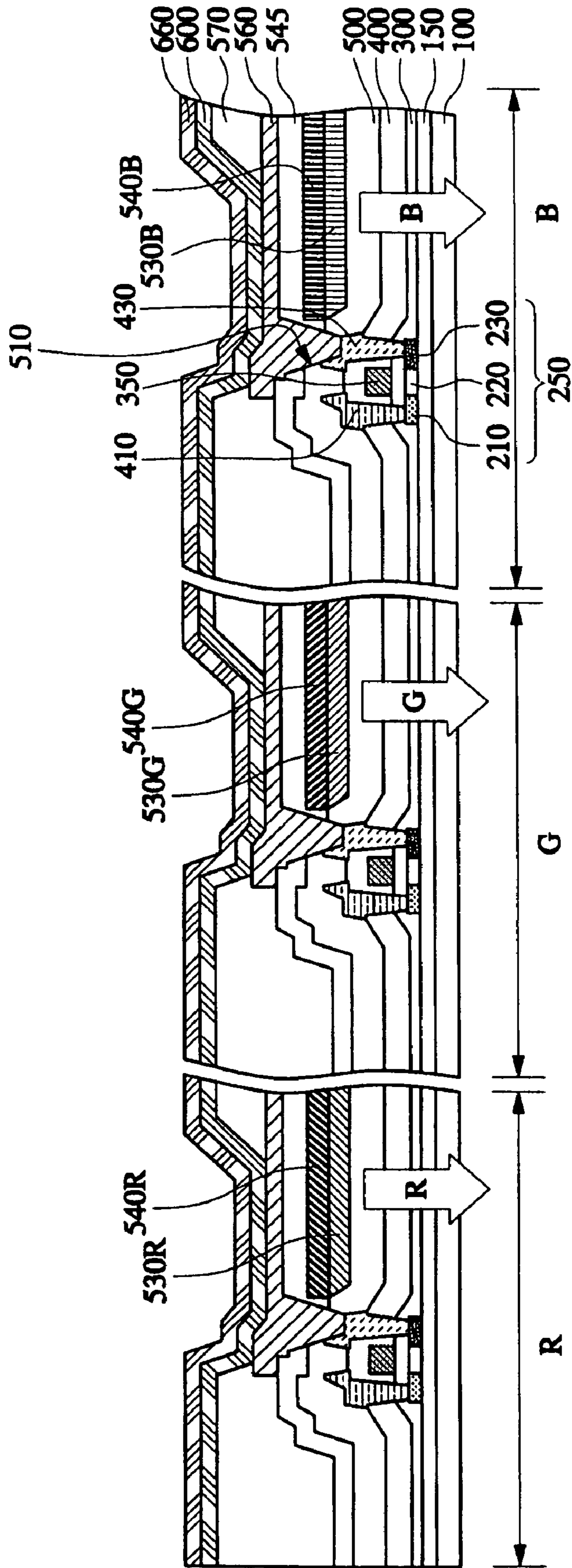


FIG. 9

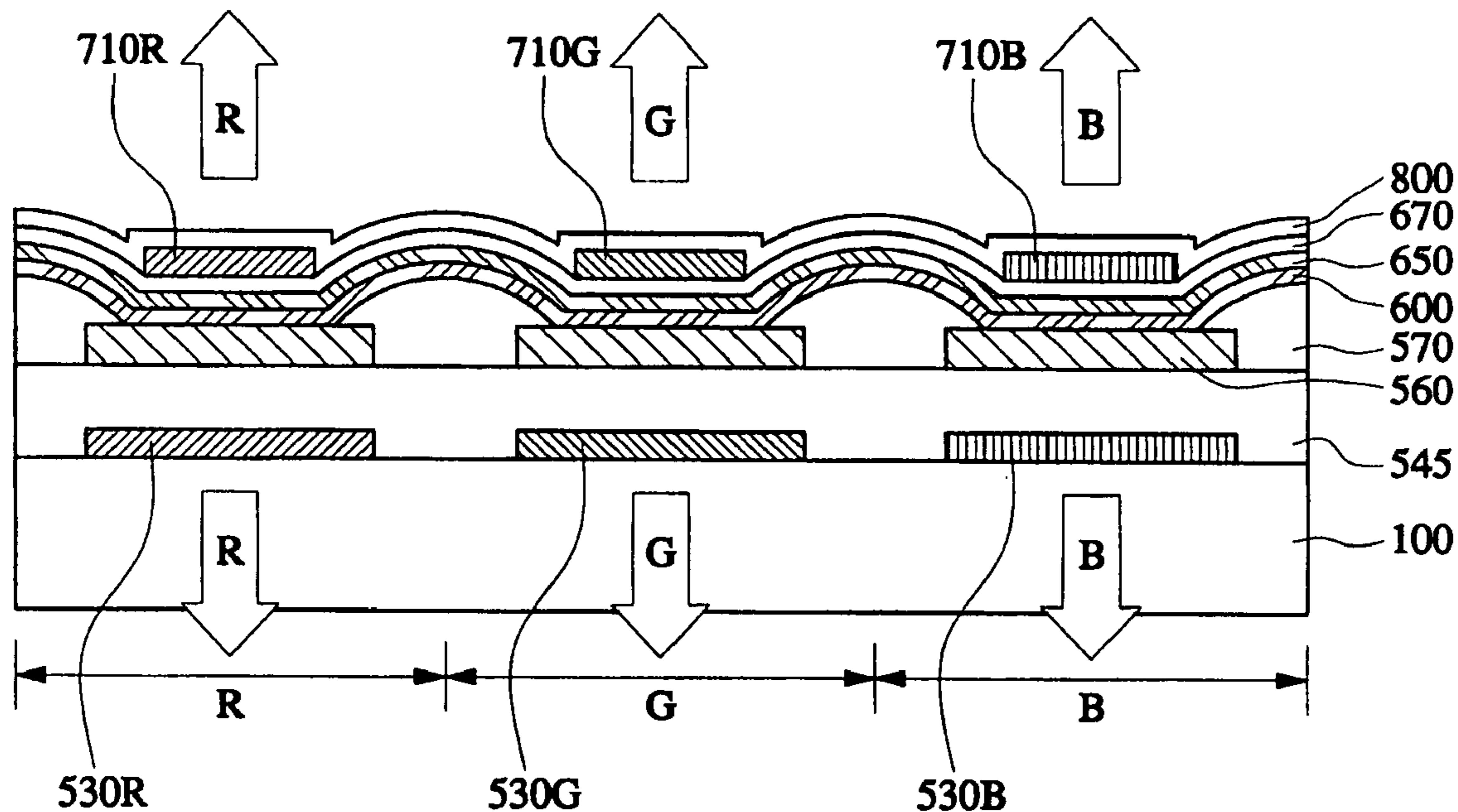


FIG. 10

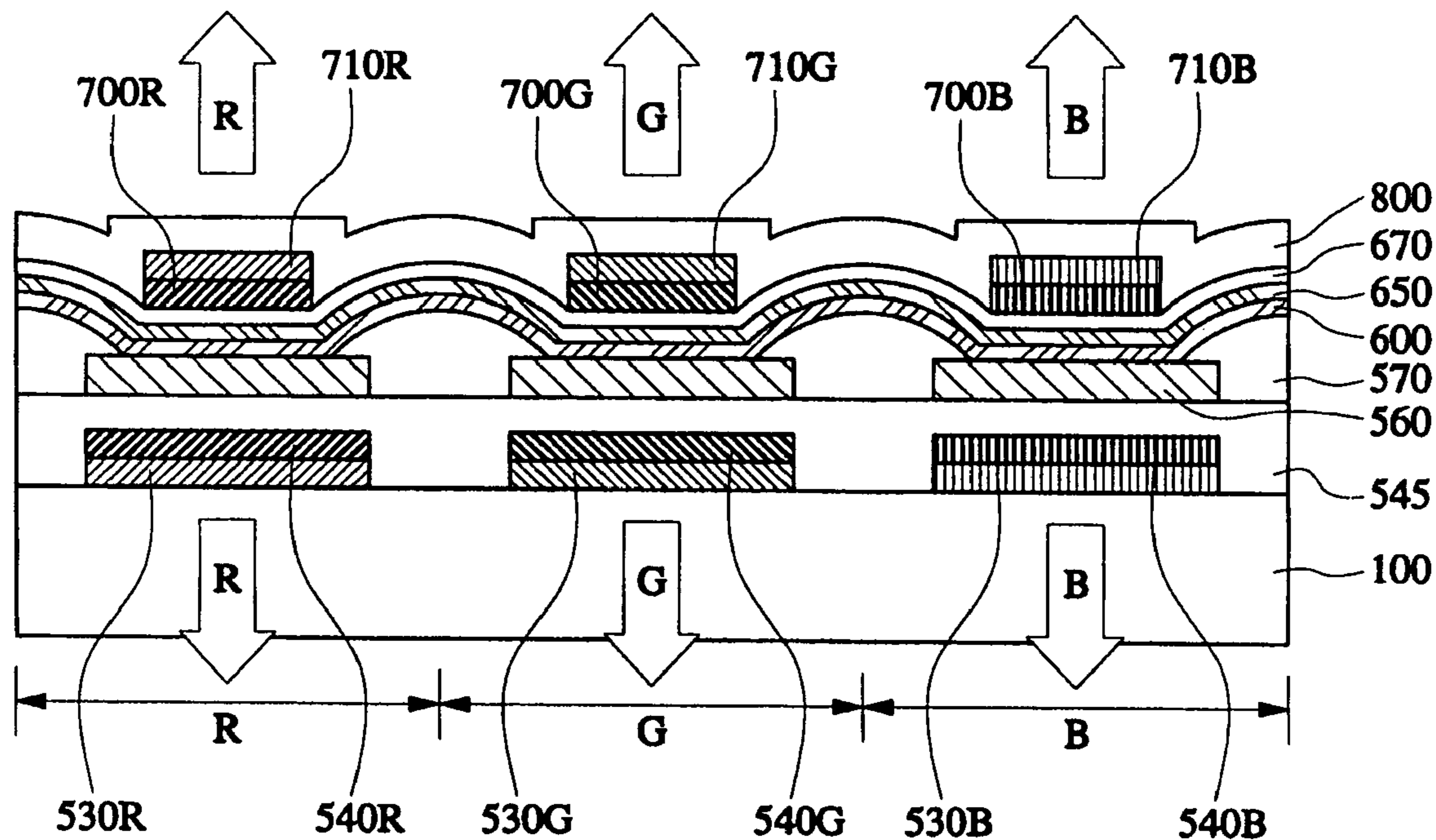


FIG. 11

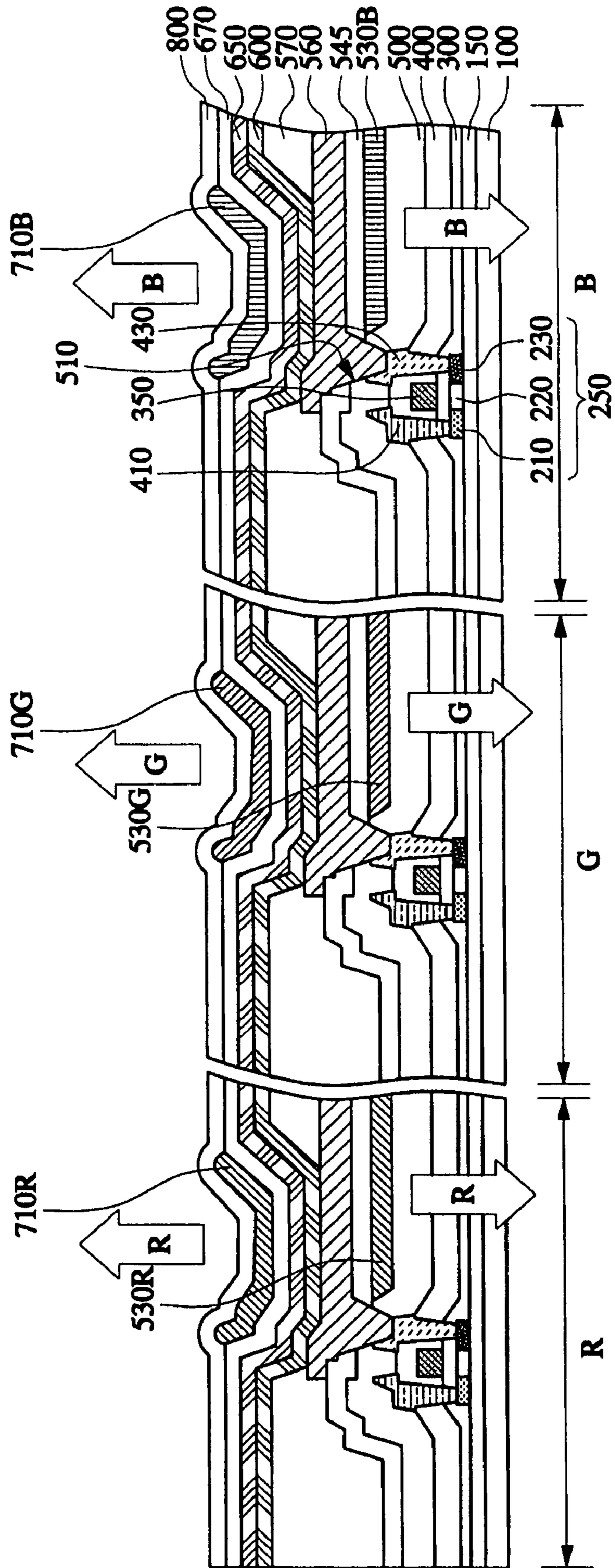
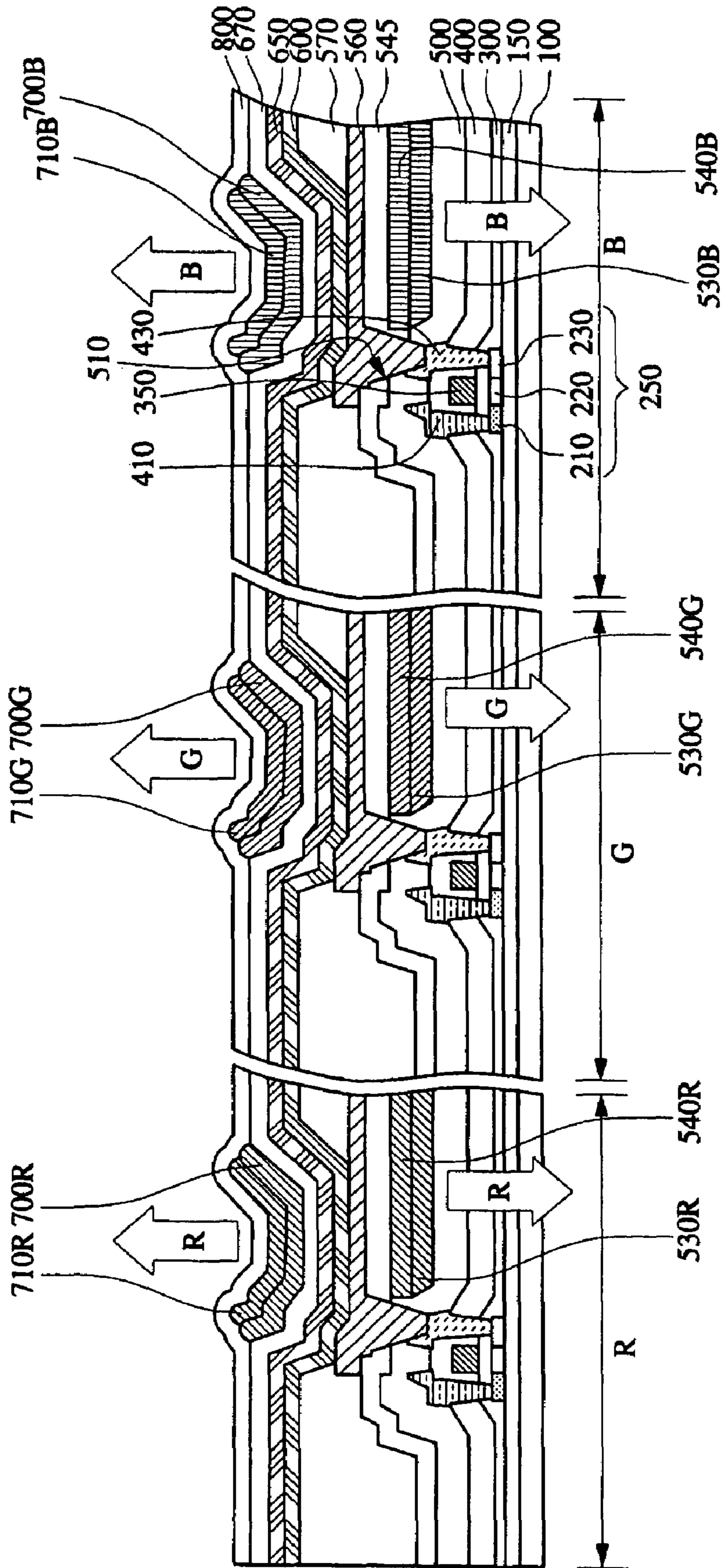


FIG. 12



1

FULL COLOR ORGANIC LIGHT-EMITTING DEVICE HAVING COLOR MODULATION LAYER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Korea Patent Appli-
cation No. 2003-65683, filed on Sep. 22, 2003, the disclo-
sure of which is hereby incorporated by reference in its
entirety and is a continuation-in-part of U.S. patent appli-
cation Ser. No. 10/914,119, filed on Aug. 10, 2004, the
disclosure of which is hereby incorporated by reference in
its entirety.

FIELD OF THE INVENTION

The present invention relates to an organic light-emitting
device (OLED) and, more particularly, to an organic light-
emitting device having color modulation layer.

BACKGROUND OF THE INVENTION

In general, an organic light-emitting device (hereinafter,
referred to as OLED) comprises a substrate, an anode
positioned on the substrate, an emission layer positioned on
the anode, and a cathode positioned on the emission layer. In
the OLED having the above structure, when a voltage is
applied between the anode and the cathode, holes and
electrons are injected into the emission layer, and then
combined in the emission layer to create excitons, which
decay radiatively. This radiation is called electrolumines-
cence (EL)

A fabrication method of a conventional full-color OLED
includes forming emission layers corresponding to red (R),
green (G) and blue (B), respectively. But in this method, the
emission layers have different lifetime characteristics one
from another, so that it is difficult to maintain white balance
when they are driven for a long time.

To solve this problem, U.S. Pat. No. 6,515,428 discloses
an OLED with a color filter (hereinafter, referred to as CF)
formed by a photolithography process and an emission layer
for emitting white color light. However, forming the CFs of
R, G and B color by the photolithography process requires
repeating the process of spin coating the CF material of each
color, as well as exposing, developing, and patterning. In
these processes, a CF previously formed may be contami-
nated by a CF material of another color which is spin coated
on the CF. Furthermore, a thermal process should be per-
formed to remove any volatile solvent, etc., contained in the
CF formed by the photolithography process. Thus, forming
the CF by the photolithography process has a disadvantage
of requiring many processes and more time to fabricate the
OLED.

U.S. Pat. No. 6,522,066 discloses an OLED with a color
conversion medium (hereinafter, referred to as CCM)
formed by the photolithography process and an emission
layer for emitting blue color light. The problems associated
with forming the CCM by the photolithography process are
often the same as those associated with forming the CF.

To solve the above problems, Korean patent application
number 2001-0000943 discloses an OLED including CFs or
CCMs formed by a vacuum deposition process. However,
forming the CFs or the CCMs using the vacuum deposition
process is performed by respectively depositing layers cor-
responding to the R, G and B using metal masks. This makes
it hard to implement a high resolution due to difficulties

2

aligning between the metal mask with the substrate. A
further disadvantage is that the layers corresponding to the
R, G and B are deposited in a separate chamber, respectively,
significantly increasing an equipment investment.

SUMMARY OF THE INVENTION

An exemplary embodiment of the present invention pro-
vides an OLED having a reduced fabrication time and a high
resolution, as well as maintaining white balance even after
it is driven for a long time. In an embodiment of the present
invention, the OLED comprises a substrate, a first electrode
positioned on the substrate and a second electrode posi-
tioned on the first electrode, wherein at least one of the first
electrode and the second electrode is a transparent electrode.
An organic functional layer includes at least an emission
layer emitting white color light is interposed between the
first and the second electrodes. A color modulation layer
formed by a laser-induced thermal imaging (hereinafter,
referred to as LITI) method is positioned on a surface
opposite to a surface adjacent to the emission layer of the
transparent electrode, wherein the color modulation layer
has at least a CCM.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the
present invention will become more apparent to those of
ordinary skill in the art by describing in detail exemplary
embodiments thereof with reference to the attached draw-
ings.

FIG. 1 and FIG. 2 are cross-sectional views illustrating an
OLED and a method for fabricating the same in accordance
with an exemplary embodiment of the present invention.

FIG. 3 and FIG. 4 are cross-sectional views illustrating an
OLED and a method for fabricating the same in accordance
with another exemplary embodiment of the present inven-
tion.

FIG. 5 and FIG. 6 are cross-sectional views illustrating an
OLED and a method for fabricating the same in accordance
with another exemplary embodiment of the present inven-
tion.

FIG. 7 and FIG. 8 are cross-sectional views illustrating an
OLED and a method for fabricating the same in accordance
with another exemplary embodiment of the present inven-
tion.

FIG. 9 and FIG. 10 are cross-sectional views illustrating
an OLED and a method for fabricating the same in accord-
ance with another exemplary embodiment of the present
invention.

FIG. 11 and FIG. 12 are cross-sectional views illustrating
an OLED and a method for fabricating the same in accord-
ance with another exemplary embodiment of the present
invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully
hereinafter with reference to the accompanying drawings, in
which exemplary embodiments of the invention are shown.
This invention may, however, be embodied in different
forms and should not be construed as limited to the embodi-
ments set forth herein. Rather, these embodiments are pro-
vided so that this disclosure will be thorough and complete,
and will fully convey the scope of the invention to those
skilled in the art. Thus, the various embodiments described

in FIGS. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 may be modified without departing from the scope of the invention. In the drawings, like numbers refer to like elements throughout the specification.

The OLED in each exemplary embodiment of the present invention comprises a substrate, a first electrode positioned on the substrate and a second electrode positioned on the first electrode. An organic functional layer is interposed between the first electrode and the second electrode and has at least an emission layer.

At least one of the first electrode and the second electrode is a transparent electrode. In detail, when the first electrode is the transparent electrode, the second electrode may be a transparent or reflective electrode, and when the first electrode is the reflective electrode, the second electrode is transparent. The transparent electrode transmits the light emitted from the emission layer. The OLED can be classified into a top-emitting type, a bottom-emitting type and a double-side-emitting type depending on the position of the transparent electrode.

The transparent electrode may be an anode or a cathode. When the transparent electrode is the cathode, the transparent electrode may be formed of a very thin layer enough to transmit the light by using, for example, Mg, Ca, Al, Ag, Ba, an alloy thereof or other similar material. When the transparent electrode is the anode, the transparent electrode may be formed of, for example, ITO (Indium Tin Oxide), IZO (Indium Zinc Oxide) or other similar material, which is a transparent conductive material. The reflective electrode may also be an anode or a cathode. When the reflective electrode is the anode, the reflective electrode may be a stacked structure having a reflective plate and a transparent layer formed of, ITO, IZO or other similar material, or a structure having a single layer consisting of one or more selected materials from a group consisting of, for example, Ni, Pt, Au, Ir, Cr, oxides thereof or other similar material. The reflective plate may be, for example, formed of AlNd or other similar material. When the reflective electrode is the cathode, the reflective electrode may be formed with a thickness enough to reflect light by using, for example, Mg, Ca, Al, Ag, Ba, an alloy thereof or other similar material.

The transparent electrode has one surface adjacent to the emission layer and another surface opposite thereof. A color modulation layer formed by a LITI method is positioned on the opposite surface. The color modulation layer modulates a color of light emitted from the emission layer to give light of a predetermined color. In this case, an emission layer of single color is formed on R, G and B pixel regions. The color modulation layers for R, G and B colors are separately formed on the R, G and B pixel regions to implement a full color OLED. Therefore, emission layers for R, G and B colors that have different lifetime characteristics from one another are not formed, so that white balance can be maintained even after it is driven for a long time. The color modulation layer is at least one of a CF and a CCM. In one embodiment, the color modulation layer may be the CF or the CCM. Alternatively, the color modulation layer may have the CF and the CCM in a stacked structure.

The CF may include a pigment and a polymer binder, and can be classified into a red CF, a green CF and a blue CF based on the type of the pigment. The red, the green and the blue CFs filter light emitted from the emission layer in wavelength ranges of red, green and blue colors, respectively. In this case, the color of light emitted from the emission layer may be white.

The CCM may include a fluorescent material and a polymer binder. The fluorescent material is excited by the

light incident from the emission layer and makes a transition to a ground state to emit light with a wavelength longer than the incident light. The CCM is classified into a red CCM, a green CCM, and a blue CCM based on the type of the fluorescent material. The red, the green and the blue CCMs convert the incident light to a red, a green, and a blue color, respectively. In this case, the color of the incident light may be white or blue.

In the stacked structure, the CCM may be positioned on a surface opposite to a surface adjacent to the emission layer of the transparent electrode, and the CF may be positioned on a surface opposite to a surface adjacent to the transparent electrode of the CCM. In this case, the red, the green and the blue CCMs convert the incident light to a red, a green, and a blue color, respectively. Thereafter, the red, the green and the blue CFs filter the red, the green and the blue colors, respectively, thereby forming clearer red, green and blue colors. In this case, the color of the incident light may be white or blue.

Forming the color modulation layer by a LITI method is performed by a method described below in detail. A light-to-heat conversion layer is formed on a base film, and a transfer layer for the color modulation layer is formed on the light-to-heat conversion layer, thereby forming a donor film. The donor film is positioned over a substrate to make the transfer layer face the substrate. A laser is irradiated on the base film of the donor film, so that the transfer layer is transferred onto the substrate, thereby forming the color modulation layer on the substrate. By repeating this method, color modulation layers for R, G and B are formed on the substrate, respectively. In accordance with the above-mentioned method, the time for fabricating the color modulation layers can be reduced compared to the photolithography process. A higher resolution can also be implemented, compared to using the vacuum deposition process.

The emission layer emitting a single color of light can be formed to have two or more sub-emission layers. In this case, the sub-emission layers emit lights having different wavelengths from one another so that the emission layer can emit a single color of light. In addition, the emission layer can be formed of a polymer material and/or a non-polymer material, and can be formed by a spin-coating or a vacuum deposition method. Other processes may also be used.

FIG. 1 and FIG. 2 are cross-sectional views illustrating a top-emitting passive matrix OLED having color modulation layers and a method for fabricating the same in accordance with an exemplary embodiment of the present invention.

Referring to FIG. 1 and FIG. 2, a substrate **100** has a red pixel region R, a green pixel region G and a blue pixel region B. A reflective layer (not shown) may be formed over an entire surface of the substrate **100**. The reflective layer prevents light from leaking through the substrate **100**. First electrodes **550** are formed to be separated from one another on the reflective layer or the substrate **100**. Each of the first electrodes **550** corresponds to each of the pixel regions R, G and B. In the present embodiment, the first electrodes **550** are formed of reflective material that can reflect the light. In addition, the first electrodes **550** may be formed as anodes or cathodes.

A pixel-defining layer **570** is formed on the substrate where the first electrodes **550** are formed. The pixel-defining layer **570** has openings to expose some portions of the surfaces of the first electrodes **550**. The pixel-defining layer **570** is, for example, formed of an acrylic-based organic layer. An organic functional layer **600** is then formed to have at least an emission layer on the exposed first electrodes **550** of the pixel regions R, G and B. The organic functional layer

600 may be formed to further include a charge transporting layer and/or a charge injection layer.

A second electrode **650** is formed across the first electrodes **550** on the organic functional layer **600**. In the present embodiment, the second electrode **650** is a transparent electrode, and light emitted from the emission layer is transmitted through the second electrode **650**. The second electrode **650** is a cathode when the first electrodes **550** are anodes, and an anode when the first electrodes **550** are cathodes. A passivation layer **670** is formed on the second electrode **650**. According to an embodiment of the invention, the passivation layer **670** may be transparent. The passivation layer **670** may be formed of one of an inorganic layer, an organic layer and a composite layer thereof. The inorganic layer is one selected from a group consisting of, for example, ITO, IZO, SiO₂, SiNx, Y₂O₃, Al₂O₃ and similar material. The organic layer may be parylene, HDPE or similar material, and the composite layer may be formed of Al₂O₃ and an organic polymer or similar material.

Thereafter, color modulation layers for R, G and B are formed by a LITI method on the passivation layer **670** to correspond to the first electrodes **550**. The color modulation layer is at least one of a CF and a CCM.

The color modulation layers may be a red CF **710R**, a green CF **710G** and a blue CF **710B** as shown in FIG. 1. In this case, the emission layer may be formed of a layer that emits white color light.

According to another exemplary embodiment of the invention, the color modulation layers may be a red CCM **700R**, a green CCM **700G** and a blue CCM **700B**, as shown in FIG. 2. In this case, the emission layer may be formed of a layer that emits blue color light or white color light. When the emission layer emits the blue color light, the blue CCM **700B** may not be formed. Although FIG. 2 illustrates a CCM stacked with a CF, it is understood that a CCM may be used alone.

Further, the color modulation layer may have a stacked structure of CFs and the CCMs by forming a red CF **710R**, a green CF **710G** and a blue CF **710B** on the CCMs **700R**, **700G** and **700B**, respectively, as shown in FIG. 2. In this case, the color modulation layer having the CF and the CCM is formed at one time by the LITI method. Alternatively, the red CCM **700R**, green CCM **700G** and blue CCM **700B** may be formed on the CFs **710R**, **710G** and **710B** respectively. In this case, the emission layer may be formed of a layer that emits blue color light or white color light.

An overcoating layer **800** may be then formed on the CFs (**710R**, **710G** and **710B** of FIG. 1 and FIG. 2) and/or on the CCMs (**700R**, **700G** and **700B** of FIG. 2) when CFs are not formed on the CCMs. The overcoating layer **800** may be a transparent layer, and may act to prevent the CFs **710R**, **710G** and **710B** or the CCMs **700R**, **700G** and **700B** from physical damage, etc. This results in fabricating a top-emitting passive matrix OLED having a color modulation layer.

FIG. 3 and FIG. 4 are cross-sectional views illustrating a top-emitting active matrix OLED having color modulation layers and a method for fabricating the same in accordance with another exemplary embodiment of the present invention.

Referring to FIG. 3 and FIG. 4, a substrate **100** has a red pixel region R, a green pixel region G and a blue pixel region B. A reflective layer (not shown) may be formed over an entire surface of the substrate **100**, and a buffer layer **150** may be formed on the reflective layer. The buffer layer **150** protects a thin film transistor (hereinafter, referred to as TFT), formed in a subsequent process, from impurities that

may smear into the TFT from the substrate **100**. Active layer **250** has a source region **210**, a drain region **230** and a channel region **220** for each of the pixel regions R, G and B. A first insulation layer **300** is formed on the active layers **250**, and gates **350** are formed on the first insulation layer **300** to correspond to the channel regions **220**, respectively. A second insulation layer **400** covering the gates **350** is formed, and source electrodes **410** and drain electrodes **430** are formed on the second insulation layer **400** to electrically connect to the source regions **210** and the drain regions **230**, respectively. The active layer **250**, source electrode **410**, drain electrode **430** and gate **350** form a TFT. A third insulation layer **500** covering the TFTs is formed, and via holes **510** are formed to expose each of the drain electrodes **430** in the third insulation layer **500**.

The first electrodes **550** are formed to be separated from one another on the substrate where the via holes **510** are formed for each of the pixel regions R, G and B. As a result, the first electrode **550** is electrically connected to the drain electrode **430**, namely, to the TFT, through the via hole **510**. In the present embodiment, the first electrode **550** is a reflective electrode that reflects the light. The first reflective electrodes **550** may be formed as anodes or cathodes.

The pixel-defining layer **570** is formed to have openings that expose some portions of surfaces of the first electrodes **550**. The pixel-defining layer **570** is, for example, formed of an acrylic-based organic layer. An organic functional layer **600** is then formed to have at least an emission layer on the exposed first electrodes **550** of the pixel regions R, G and B. The organic functional layer **600** may be formed to further include a charge transporting layer and/or a charge injection layer.

The second electrodes **650** are formed on the organic functional layer **600**. In the present embodiment, the second electrode **650** is a transparent electrode, and the light emitted from the emission layer is transmitted through the second electrode **650**. The second electrode **650** is a cathode when the first electrode **550** is an anode, and an anode when the first electrode **550** is a cathode. The passivation layer **670** is formed on the second electrode **650**, and the passivation layer **670** may be transparent. The passivation layer **670** may be formed of one of an inorganic layer, an organic layer and a composite layer thereof. According to an exemplary embodiment of the invention, the inorganic layer may be one selected from a group consisting of ITO, IZO, SiO₂, SiNx, Y₂O₃, Al₂O₃, and similar materials, the organic layer is parylene, HDPE or similar material, and the composite layer is formed of Al₂O₃ and an organic polymer, or similar material.

Color modulation layers are formed using a LITI method on the passivation layer **670** to correspond to the first electrodes **550**. The color modulation layer is at least one of a CF and a CCM. According to an exemplary embodiment of the present invention, the color modulation layers may be a red CF **710R**, a green CF **710G** and a blue CF **710B**, as shown in FIG. 3. In this case, the emission layer may be formed of a layer that emits white color light.

According to another exemplary embodiment of the invention, the color modulation layers may be a red CCM **700R**, a green CCM **700G** and a blue CCM **700B**, as shown in FIG. 4. In this case, the emission layer may be formed of a layer that emits blue color light or white color light. When the emission layer emits the blue color light, the blue CCM **700B** may not be formed. Like the previous embodiment, although FIG. 4 illustrates a CCM stacked with a CF, it is understood that a CCM may be used alone.

The color modulation layer further may have a stacked structure of a CF and the CCM by forming a red CF **710R**, a green CF **710G** and a blue CF **710B** on the CCMs **700R**, **700G** and **700B**, respectively as shown in FIG. 4. In this case, the color modulation layer having the CF and the CCM

may be formed at one time by the LITI method. Alternatively, the red CCM **700R**, green CCM **700G** and blue CCM **700B** may be formed on the CFs **710R**, **710G** and **710B** respectively. In this case, the emission layer may be formed of a layer that emits blue color light or white color light.

The overcoating layer **800** is then formed on the CFs (**710R**, **710G** and **710B** of FIG. 3 and FIG. 4) or on the CCMs (**700R**, **700G** and **700B** of FIG. 4) when the CFs **710R**, **710G** and **710B** are not formed on the CCMs **700R**, **700G** and **700B**. The overcoating layer **800** is a transparent one, and prevents the CFs **710R**, **710G** and **710B** or the CCMs **700R**, **700G** and **700B** from physical damages, etc. As a result, the top-emitting active matrix OLED having the color modulation layer is fabricated.

FIG. 5 and FIG. 6 are cross-sectional views illustrating a bottom-emitting passive matrix OLED having color modulation layers and a method for fabricating the same in accordance with another exemplary embodiment of the present invention.

Referring to FIG. 5 and FIG. 6, the substrate **100** having a red pixel region R, a green pixel region G and a blue pixel region B is provided. In the present embodiment, the substrate **100** is transparent and can transmit light.

Color modulation layers are formed using a LITI method on the substrate **100** to be separated from one another, each for the pixel regions R, G and B. The color modulation layer is at least one of a CF and a CCM.

The color modulation layers may be a red CF **530R**, a green CF **530G** and a blue CF **530B**, as shown in FIG. 5. In this case, an emission layer to be formed in a subsequent process is formed to emit white color light.

The color modulation layers also may be a red CCM **540R**, a green CCM **540G** and a blue CCM **540B**, as shown in FIG. 6. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light, and the blue CCM **540B** may not be formed when the emission layer emits the blue color light. Although FIG. 6 shows a CCM stacked with a CF, it is understood that a CCM may be used alone.

Further, the color modulation layer may have a stacked structure of a CF and the CCM by forming a red CF **530R**, a green CF **530G** and a blue CF **530B** before forming the CCMs **540R**, **540G** and **540B** as shown in FIG. 6. In this case, the color modulation layer having the CF and the CCM is formed at one time by the LITI method. Alternatively, the red CCM **540R**, green CCM **540G** and blue CCM **540B** may be formed on the CFs **530R**, **530G** and **530B** respectively. In this case, the emission layer to be formed in a subsequent process may be formed of a layer that emits blue color light or white color light.

An overcoating layer **545** is formed on the CFs (**530R**, **530G** and **530B** of FIG. 5) and/or the CCMs (**540R**, **540G** and **540B** of FIG. 6). The overcoating layer **545** is a transparent one, and prevents the CFs **530R**, **530G** and **530B** or the CCMs **540R**, **540G** and **540B** from physical damages, etc, and also covers steps that may occur due to the formation of the CCMs **540R**, **540G** and **540B** or the CFs **530R**, **530G** and **530B**.

The first electrodes **560** are formed on the overcoating layer **545** to correspond to the CFs **530R**, **530G** and **530B**, respectively. In the present embodiment, the first electrodes **560** are transparent, and the light emitted from the emission

layer to be formed in a subsequent process is transmitted through the first electrodes **560**. The first electrodes **560** may be formed as anodes or cathodes. The pixel-defining layer **570** is formed to have openings, which expose some portions of surfaces of the first electrodes **560** on the substrate **100** where the first electrodes **560** are formed. The pixel-defining layer **570** is, for example, formed of an acrylic-based organic layer or similar material. An organic functional layer **600** is then formed to have at least an emission layer on the exposed first electrodes **560** of the pixel regions R, G and B. The organic functional layer **600** may be formed to further include a charge transporting layer and/or a charge injection layer.

The second electrodes **660** are formed across the first electrodes **560** on the organic functional layer **600**. In the present embodiment, the second electrode **660** is reflective and reflects the light emitted from the emission layer. The second electrode **660** is formed as a cathode when the first electrodes **560** are anodes, and an anode when the first electrodes **560** are cathodes. As a result, the bottom-emitting passive matrix OLED having the color modulation layers is fabricated.

FIG. 7 and FIG. 8 are cross-sectional views illustrating a bottom-emitting active matrix OLED having color modulation layers and a method for fabricating the same in accordance with another exemplary embodiment of the present invention.

Referring to FIG. 7 and FIG. 8, a substrate **100** having a red pixel region R, a green pixel region G and a blue pixel region B is provided. In the present embodiment, the substrate **100** is transparent and can transmit the light. A buffer layer **150** may be formed on the substrate **100**. Active layer **250** is formed to have a source region **210**, a drain region **230** and a channel region **220**, each for the pixel regions R, G and B. A first insulation layer **300** is formed on the active layers **250**, and gates **350** are formed on the first insulation layer **300** to correspond to the channel regions **220**, respectively.

A second insulation layer **400** covering the gates **350** is formed, and source electrodes **410** and drain electrodes **430** are formed on the second insulation layer **400** to electrically connect to the source regions **210** and the drain regions **230**, respectively. The active layer **250**, source electrode **410**, drain electrode **430** and gate **350** form a TFT. A third insulation layer **500** covering the TFTs is formed. The buffer layer **150**, the TFT and the third insulation layer **500** may be the same as explained in the exemplary embodiment of FIG. 3 and FIG. 4. In each of the pixel regions R, G and B, regions where the TFTs are formed may be light shielding regions that shield the light emitted from the emission layer to be formed in a subsequent process. Remaining regions except the light shielding regions may be light transmitting regions that transmit the light emitted from the emission layer to be formed in the subsequent process.

Color modulation layers are formed using LITI on the third insulation layer **500** of the light transmitting regions, each for the pixel regions R, G and B. Alternatively, as is not shown in the figure, color modulation layers may be formed between the third insulation layer **500** and the second insulation layer **400**, between the second insulation layer **400** and the first insulation layer **300**, between the first insulation layer **300** and the buffer layer **150**, and/or between the buffer layer **150** and the substrate **100** in the light transmitting regions. The color modulation layer is at least one of a CF and a CCM.

The color modulation layers may be a red CF **530R**, a green CF **530G** and a blue CF **530B**, as shown in FIG. 7. In

this case, an emission layer to be formed in a subsequent process is formed to emit white color light.

In the mean time, the color modulation layers may be a red CCM **540R**, a green CCM **540G** and a blue CCM **540B**, as shown in FIG. **8**. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light, and the blue CCM **540B** may not be formed when the emission layer emits the blue color light. Although FIG. **8** shows stacked structure of CCM and CF, it is also understood that a CCM can be used alone.

Further, the color modulation layer may have a stacked structure of a CF and a CCM by forming a red CF **530R**, a green CF **530G** and a blue CF **530B** before forming the CCMs **540R**, **540G** and **540B**, as shown in FIG. **8**. In this case, the color modulation layer having the CF and the CCM is formed at one time by the LITI method. Alternatively, CCMs **540R**, **540G** and **540B** may be formed before CFs **530R**, **530G** and **530B**, respectively. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light.

When the CFs (**530R**, **530G** and **530B** of FIG. **7**) and/or the CCMs (**540R**, **540G** and **540B** of FIG. **8**) are formed on the third insulation layer **500**, the overcoating layer **545** may be formed on the CFs (**530R**, **530G** and **530B** of FIG. **7**), or the CCMs (**540R**, **540G** and **540B** of FIG. **8**).

Via holes **510** are formed to expose each of the drain electrodes **430** within the third insulation layer **500** and the overcoating layer **545**. First electrodes **560** are formed on the exposed drain electrodes **430** and the overcoating layer **545** of the light transmitting regions to correspond to the color modulation layers, respectively. The first electrode **560** is electrically connected to the drain electrode **430**, namely the TFT through the via hole **510**. In the present embodiment, the first electrodes **560** are transparent, and the light emitted from the emission layer to be formed in a subsequent process is transmitted through the first electrodes **560**. The first transparent electrodes **560** may be formed as anodes or cathodes.

The pixel-defining layer **570** is formed to have openings which expose some portions of surfaces of the first electrodes **560**. An organic functional layer **600** is then formed to have at least an emission layer on exposed first electrodes **560** of pixel regions R, G and B. The organic functional layer **600** may be formed to further include a charge transporting layer and/or a charge injection layer.

The second electrodes **660** are formed on the organic functional layer **600**. In the present embodiment, the second electrode **660** is reflective and reflects the emitted light from the emission layer. The second electrode **660** is formed as a cathode when the first electrodes **560** are anodes, and an anode when the first electrodes **560** are cathodes. As a result, the bottom-emitting active matrix OLED having the color modulation layers is fabricated.

FIG. **9** and FIG. **10** are cross-sectional views illustrating a double-side emitting passive matrix OLED having color modulation layers and a method for fabricating the same in accordance with another exemplary embodiment of the present invention.

Referring to FIG. **9** and FIG. **10**, the substrate **100** has a red pixel region R, a green pixel region G and a blue pixel region B. In an exemplary embodiment of the present embodiment, the substrate **100** can transmit light.

First color modulation layers are formed, using LITI, on the substrate **100** to be separated from one another for each of the pixel regions R, G and B. The first color modulation layer is at least one of a CF and a CCM.

The first color modulation layers may be a first red CF **530R**, a first green CF **530G** and a first blue CF **530B**, as shown in FIG. **9**. In this case, an emission layer to be formed in a subsequent process is formed to emit white color light.

The first color modulation layers also may be a first red CCM **540R**, a first green CCM **540G** and a first blue CCM **540B**, as shown in FIG. **10**. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light, and the first blue CCM **540B** may not be formed when the emission layer emits the blue color light.

Further, the first color modulation layer may have a stacked structure of a first CF and the first CCM by forming a first red CF **530R**, a first green CF **530G** and a first blue CF **530B** before forming the first CCMs **540R**, **540G** and **540B** as shown in FIG. **10**. In this case, the first color modulation layer having the first CF and the first CCM may be formed at one time by the LITI method. Alternatively, CCMs **540R**, **540G** and **540B** may be formed before CFs **530R**, **530G** and **530B**, respectively. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light.

The first overcoating layer **545** is formed on the substrate **100** where the first CFs (**530R**, **530G** and **530B** of FIG. **9**) and/or the first CCMs (**540R**, **540G** and **540B** of FIG. **10**) are formed. The first overcoating layer **545** is transparent, and prevents the first CFs **530R**, **530G** and **530B** and/or the first CCMs **540R**, **540G** and **540B** from physical damages, etc, and also covers steps that may occur due to the formation of the first CCMs **540R**, **540G** and **540B**, and/or the first CFs **530R**, **530G** and **530B**.

The first electrodes **560** are formed on the first overcoating layer **545** to correspond to the first CFs **530R**, **530G** and **530B**, respectively. In the present embodiment, the first electrodes **560** are transparent electrodes, and the light emitted from the emission layer to be formed in the subsequent process is transmitted through the first electrodes **560**. The first electrodes **560** may be formed as anodes or cathodes. The pixel-defining layer **570** is formed to have openings which expose some portions of surfaces of the first electrodes **560**. The pixel-defining layer **570** is, for example, formed of an acrylic-based organic layer or similar material. An organic functional layer **600** is formed to have at least an emission layer on the exposed first electrodes **560** of the pixel regions R, G and B. The organic functional layer **600** may be formed to further include a charge transporting layer and/or a charge injection layer.

The second electrodes **650** are formed across the first electrodes **560** on the organic functional layer **600**. In the present embodiment, the second electrode **650** is also transparent, and light emitted from the emission layer is transmitted through the first electrodes **560** and the second electrode **650**. The second electrode **650** is a cathode when the first electrodes **560** are anodes, and an anode when the first electrodes **560** are cathodes. A passivation layer **670** is formed on the second electrode **650**. The passivation layer **670** may be formed of an inorganic layer, an organic layer, or a composite layer thereof. The inorganic layer may be one selected from a group consisting of ITO, IZO, SiO₂, SiNx, Y₂O₃, Al₂O₃ or similar material. The organic layer may be parylene, HDPE or other similar material, and the composite layer may be formed of Al₂O₃ and an organic polymer, or similar material.

Second color modulation layers are formed using LITI method on the passivation layer **670** to correspond to the first electrodes **560**. The second color modulation layer is at least one of a CF and a CCM.

The second color modulation layers may be a second red CF **710R**, a second green CF **710G** and a second blue CF **710B** as shown in FIG. **9**. In this case, the emission layer may be formed of one that emits white color light.

The second color modulation layers may also be a second red CCM **700R**, a second green CCM **700G** and a second blue CCM **700B**, as shown in FIG. **10**. In this case, the emission layer may be formed of one that emits blue color light or white color light. When the emission layer emits the blue color light, the second blue CCM **700B** may not be formed.

Further, the second color modulation layer may have a stacked structure of a CF and the second CCM by forming a second red CF **710R**, a second green CF **710G** and a second blue CF **710B** on the CCMs **700R**, **700G** and **700B**, respectively as shown in FIG. **10**. In this case, the second color modulation layer having the second CF and the second CCM may be formed at one time by the LITI method. Alternatively, the red CCM **700R**, green CCM **700G** and blue CCM **700B** may be formed on the CFs **710R**, **710G** and **710B**, respectively. In this case, the emission layer may be formed of one that emits blue color light or white color light.

A second overcoating layer **800** is formed on the second CFs (**710R**, **710G** and **710B** of FIG. **9** and FIG. **10**) and/or on the second CCMs (**700R**, **700G** and **700B** of FIG. **10**) when the second CFs are not formed on the second CCMs. The second overcoating layer **800** is transparent, and acts to prevent the second CFs (**710R**, **710G** and **710B** of FIG. **9** and FIG. **10**) and/or the second CCMs (**700R**, **700G** and **700B** of FIG. **10**) from physical damages, etc. As a result, the double-side-emitting passive matrix OLED having the color modulation layers is fabricated.

FIG. **11** and FIG. **12** are cross-sectional views illustrating a double-side-emitting active matrix OLED having color modulation layers and a method for fabricating the same in accordance with another exemplary embodiment of the present invention.

Referring to FIG. **11** and FIG. **12**, the substrate **100** has a red pixel region **R**, a green pixel region **G** and a blue pixel region **B**. In the present embodiment, the substrate **100** is transparent and can transmit light. A buffer layer **150** may be formed on the substrate **100**. Active layers **250** are formed to have source regions **210**, drain regions **230** and channel regions **220**, for each of the pixel regions **R**, **G** and **B**. A first insulation layer **300** is formed on the active layers **250**, and gates **350** are formed on the first insulation layer **300** to correspond to the channel regions **220**, respectively.

A second insulation layer **400** covering the gates **350** is formed, and source electrodes **410** and drain electrodes **430** are formed on the second insulation layer **400** to electrically connect to the source regions **210** and the drain regions **230**, respectively. The active layer **250**, the source electrode **410**, the drain electrode **430** and the gate **350** form a TFT. A third insulation layer **500** covering the TFTs is formed. The buffer layer **150**, the TFT and the third insulation layer **500** may be the same as that in the exemplary embodiment of FIG. **3** and FIG. **4**. In each of the pixel regions **R**, **G** and **B** of the substrate **100**, regions where the TFT is formed may be light shielding regions that shield the light emitted from the emission layer to be formed in a subsequent process, and remaining regions except the light shielding regions may be light transmitting regions that transmit the light emitted from the emission layer to be formed in the subsequent process.

First color modulation layers are formed using LITI method on the third insulation layer **500** of the light transmitting regions for each of the pixel regions **R**, **G** and **B**. Alternatively, as is not shown in the figure, the first color

modulation layers may be formed between the third insulation layer **500** and the second insulation layer **400**, between the second insulation layer **400** and the first insulation layer **300**, between the first insulation layer **300** and the buffer layer **150**, or between the buffer layer **150** and the substrate **100** in the light transmitting regions. The first color modulation layer is at least one of a CF and a CCM.

The first color modulation layers may be a first red CF **530R**, a first green CF **530G** and a first blue CF **530B**, as shown in FIG. **11**. In this case, an emission layer to be formed in a subsequent process is formed to emit white color light.

The first color modulation layers may also be a first red CCM **540R**, a first green CCM **540G** and a first blue CCM **540B**, as shown in FIG. **12**. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light, and the first blue CCM **540B** may not be formed when the emission layer emits the blue color light.

Further, the first color modulation layer may have a stacked structure of a CF and the first CCM by forming a first red CF **530R**, a first green CF **530G** and a first blue CF **530B** before forming the first CCMs **540R**, **540G** and **540B** as shown in FIG. **12**. In this case, the first color modulation layer having the first CF and the first CCM may be formed at one time by the LITI method. Alternatively, CCMs **540R**, **540G** and **540B** may be formed before forming CFs **530R**, **530G** and **530B**. In this case, the emission layer to be formed in a subsequent process may be formed of one that emits blue color light or white color light.

When the first CFs (**530R**, **530G** and **530B** of FIG. **11**) or the first CCMs (**540R**, **540G** and **540B** of FIG. **12**) are formed on the third insulation layer **500**, the first overcoating layer **545** may be formed on the first CFs **530R**, **530G** and **530B**, and/or the first CCMs **540R**, **540G** and **540B**.

Via holes **510** are formed to expose each of the drain electrodes **430** within the third insulation layer **500** and the overcoating layer **545**. First electrodes **560** are formed on the exposed drain electrodes **430** and the overcoating layer **545** of the light transmitting regions to correspond to the color modulation layers, respectively. The first electrode **560** is electrically connected to the drain electrode **430** through the via hole **510**. In the present embodiment, the first electrodes **560** are transparent, and the light emitted from the emission layer to be formed in the subsequent process is transmitted through the first electrodes **560**. The first transparent electrodes **560** may be anodes or cathodes.

The pixel-defining layer **570** is formed to have openings, which expose some portions of surfaces of the first electrodes **560**. An organic functional layer **600** is formed to have at least an emission layer on the exposed first electrodes **560** of the pixel regions **R**, **G** and **B**. The organic functional layer **600** may be formed to further include a charge transporting layer and/or a charge injection layer.

The second electrodes **650** are formed on the organic functional layer **600**. In the present embodiment, the second electrode **650** is also transparent, and the light emitted from the emission layer is transmitted through the first electrodes **560** as well as the second electrode **650**. The second electrode **650** is a cathode when the first electrodes **560** are anodes, and an anode when the first electrodes **560** are cathodes. A passivation layer **670** is formed on the second electrode **650**. The passivation layer **670** may be formed of one of an inorganic layer, an organic layer, and a composite layer thereof. The inorganic layer may be selected from a group consisting of ITO, IZO, SiO₂, SiN_x, Y₂O₃, Al₂O₃ or other similar material. The organic layer may be parylene,

HDPE or other similar material. And the composite layer may be formed of Al_2O_3 and an organic polymer or other similar material.

Second color modulation layers are formed using the LITI method on the passivation layer **670** to correspond to the first electrodes **560**. The second color modulation layer is at least one of a CF and a CCM.

The second color modulation layers may be a second red CF **710R**, a second green CF **710G** and a second blue CF **710B** as shown in FIG. **11**. In this case, the emission layer may be formed of one that emits white color light.

The second color modulation layers may also be a second red CCM **700R**, a second green CCM **700G** and a second blue CCM **700B**, as shown in FIG. **12**. In this case the emission layer may be formed of one that emits blue color light or white color light, the second blue CCM **700B** may not be formed when the emission layer emit blue color light.

The second color modulation layer may have a stacked structure of the second CF and the second CCM by forming a second red CF **710R**, a second green CF **710G** and a second blue CF **710B** on the CCMs **700R**, **700G** and **700B**, respectively as shown in FIG. **12**. In this case, the second color modulation layer having the second CF and the second CCM is formed at one time by the LITI method. Alternatively, CCMs **700R**, **700G** and **700B** may be formed on CFs **710R**, **710G** and **710B**, respectively. In this case the emission layer may be formed of one that emits blue color light or white color light

The overcoating layer **800** is formed on the second CFs (**710R**, **710G** and **710B** of FIG. **11** and FIG. **12**) and/or on the second CCMs (**700R**, **700G** and **700B** of FIG. **12**) when the second CFs are not formed on the second CCMs. The overcoating layer **800** is transparent, and prevents the second CFs **710R**, **710G** and **710B** and/or the second CCMs **700R**, **700G** and **700B** from physical damages, etc. As a result, the double-side-emitting active matrix OLED having the color modulation layers is fabricated.

Hereinafter, an experimental example is described for better understanding of the present invention. However, the present invention is not limited to this example.

The following experimental and comparative examples are the examples for examining the quality of the CF pattern

layer was transferred onto the substrate. In the transfer process, the laser power was 10 W, and the scanning speed of the laser was 7 m/sec. This process was repeated for each of red, green and blue colors, so that patterns for the red, green and blue CFs were formed on the substrate. Anode patterns were then formed on the CF patterns, respectively, and an emission layer emitting white color light was formed on the anodes. Cathodes were then formed on the emission layer, so that a full color OLED was fabricated.

COMPARATIVE EXAMPLE

A substrate was prepared, and a photoresist (Red6011L for the red color; Green6011L for the green color; Blue6001L for the blue color, all manufactured by Fuji Hunt Co.) for the CF was deposited on the substrate and then exposed and developed to form a pattern for the CF. This process was repeated for each of the red, green and blue colors, so that patterns for the red, green and blue CFs were formed. Anode patterns were then formed on the CF patterns, respectively, and an emission layer emitting white color light was formed on the anodes. Cathodes were then formed on the emission layer, so that a full color OLED was fabricated.

TABLE 1

Pattern quality	Experimental example		
	Red color	Green color	Blue color
Pattern width (μm)	94.89 ± 1.08	99.98 ± 1.46	106.30 ± 0.70
Pattern edge roughness (μm)	1.23 ± 0.36	1.51 ± 0.46	0.62 ± 0.26
Pattern surface roughness (μm)	0.039 ± 0.009	0.064 ± 0.018	0.036 ± 0.012

When the pattern width for the CFs in accordance with the comparative example is the same as that of the experimental example, the pattern edge roughness of the comparative example is about $2 \pm 0.1 \mu\text{m}$. As can be seen in Table 1, the quality of the pattern for the CFs shows an improved result for the pattern edge roughness.

TABLE 2

Optical characteristic	Experimental example				Comparative example			
	Red	Green	Blue	White	Red	Green	Blue	White
Chromaticity coordinate x	0.597	0.314	0.140	0.319	0.615	0.304	0.139	0.306
Chromaticity coordinate y	0.35	0.534	0.158	0.355	0.339	0.542	0.155	0.343
Chromaticity coordinate Y	27.16	63.53	18.65	36.62	21.53	59.94	17.98	33.15
Transmittance (% at 460 nm)	87.4	82.9	73.7	—	87.15	80.06	75.62	—
Color reproducibility (%)	43.75				48.63			

and optical characteristics of the OLED having the CF in accordance with the present invention.

EXPERIMENTAL EXAMPLE

Material for the CF (manufactured by 3M Co.) was deposited on a donor film (manufactured by 3M Co.) to form a transfer layer, while preparing a substrate. The donor film was arranged to make the transfer layer face the substrate and was irradiated by an Nd-YAG laser, so that the transfer

Referring to the Table 2, the x, y and the transmittance of the each color of the experimental example are similar to that of the comparative example. But the white Y and the color reproducibility of the experimental example have been improved about 10.5% and about 4.9%, respectively, compared to that of the comparative example.

As mentioned above, the emission layer having a single color is formed on the pixel regions R, G and B, and the color modulation layers are formed by the LITI method on

15

the pixel regions R, G and B, respectively, so that white balance can be maintained even after it is driven for a long time. The time for the fabrication process can be reduced and high resolution can be implemented at the same time. In addition, it is expected that the optical characteristic and the pattern quality of the color modulation layers may be improved.

While the present invention has been described with reference to a particular embodiment, it is understood that the disclosure has been made for purpose of illustrating the invention by way of examples and is not limited to limit the scope of the invention. And one skilled in the art can make amend and change the present invention without departing from the scope and spirit of the invention.

What is claimed is:

1. An organic light-emitting device, comprising:
 - a substrate; and
 - a first pixel region, a second pixel region, and a third pixel region, wherein each pixel region comprises:
 - a first electrode positioned on the substrate;
 - a second electrode positioned on the first electrode, wherein at least one of the first electrode and the second electrode is a transparent electrode;
 - an organic functional layer interposed between the first and the second electrodes, where the organic functional layer includes an emission layer emitting white color light; and
 - a color modulation layer positioned on a surface opposite to a surface adjacent to the emission layer of the transparent electrode, wherein the color modulation layer comprises a color conversion medium and is formed by a laser-induced thermal imaging method, wherein the color modulation layer in the first pixel region is separated from the color modulation layer in the second pixel region and the color modulation layer in the third pixel region.
2. The organic light-emitting device of claim 1, wherein the color modulation layer has a stacked structure of the color conversion medium and a color filter.
3. The organic light-emitting device of claim 2, wherein the color conversion medium is positioned on a surface opposite to a surface adjacent to the emission layer of the transparent electrode, and the color filter is positioned on a surface opposite to a surface adjacent to the transparent electrode of the color conversion medium.
4. The organic light-emitting device of claim 2, wherein the color modulation layer having the color conversion medium and the color filter is formed at one time by the laser-induced thermal imaging method.
5. The organic light-emitting device of claim 1, wherein the emission layer comprises at least one of a polymer material and a non-polymer material.
6. The organic light-emitting device of claim 1, wherein the emission layer has a stacked structure of at least two sub-emission layers.
7. The organic light-emitting device of claim 1, wherein the emission layer is formed by at least one of a vacuum deposition method and a spin-coating method.
8. The organic light-emitting device of claim 1, wherein the organic functional layer further includes at least one of a charge injection layer and a charge transporting layer.
9. The organic light-emitting device of claim 1, further comprising a thin film transistor electrically coupled to the first electrode.
10. The organic light-emitting device of claim 1, wherein the second electrode is the transparent electrode when the

16

first electrode is a reflective electrode, and the color modulation layer is positioned on the second electrode.

11. The organic light-emitting device of claim 10, further comprising a thin film transistor electrically coupled to the first electrode.

12. The organic light-emitting device of claim 10, further comprising a passivation layer interposed between the second electrode and the color modulation layer.

13. The organic light-emitting device of claim 12, wherein the passivation layer is one of an inorganic layer, an organic layer, and a composite layer of an inorganic layer and an organic layer.

14. The organic light-emitting device of claim 10, further comprising an overcoating layer on the color modulation layer.

15. The organic light-emitting device of claim 1, wherein the first electrode is the transparent electrode when the second electrode is a reflective electrode, and the color modulation layer is positioned between the substrate and the first electrode.

16. The organic light-emitting device of claim 15, further comprising an overcoating layer interposed between the first electrode and the color modulation layer.

17. The organic light-emitting device of claim 15, further comprising a thin film transistor coupled to the first electrode.

18. The organic light-emitting device of claim 15, further comprising:

- an active layer having a source region, a drain region and a channel region;
 - a first insulation layer positioned on the active layer;
 - a gate electrode positioned on the first insulation layer to correspond to the channel region;
 - a second insulation layer positioned on the gate electrode;
 - a source electrode and a drain electrode positioned on the second insulation layer and connected to the source region and the drain region, respectively; and
 - a third insulation layer positioned on the source electrode and the drain electrode and having a via hole exposing one of the source electrode and the drain electrode;
- wherein the first electrode is positioned on the third insulation layer and connected to the exposed one of the source electrode and the drain electrode through the via hole, and the color modulation layer is positioned between the first electrode and the substrate.

19. The organic light-emitting device of claim 18, wherein the color modulation layer is positioned in at least one place of a place between the first electrode and the third insulation layer, a place between the third insulation layer and the second insulation layer, a place between the second insulation layer and the first insulation layer, and a place between the first insulation layer and the substrate.

20. The organic light-emitting device of claim 19, further comprising an overcoating layer interposed between the first electrode and the color modulation layer, when the color modulation layer is positioned between the first electrode and the third insulation layer.

21. The organic light-emitting device of claim 1, wherein the first electrode and the second electrode are transparent, the color modulation layer includes a first color modulation layer positioned between the substrate and the first electrode, and a second color modulation layer positioned on the second electrode.

22. The organic light-emitting device of claim 21, further comprising a first overcoating layer interposed between the first electrode and the first color modulation layer.

17

23. The organic light-emitting device of claim 21, further comprising a passivation layer between the second color modulation layer and the second electrode.

24. The organic light-emitting device of claim 23, wherein the passivation layer is one of an inorganic layer, an organic layer, and a composite layer of an inorganic layer and an organic layer.

25. The organic light-emitting device of claim 21, further comprising a second overcoating layer on the second color modulation layer.

26. The organic light-emitting device of claim 21, further comprising a thin film transistor coupled to the first electrode.

27. The organic light-emitting device of claim 21, further comprising:

an active layer having a source region, a drain region and a channel region;

a first insulation layer positioned on the active layer;

a gate electrode positioned on the first insulation layer to correspond to the channel region;

a second insulation layer positioned on the gate electrode;

a source electrode and a drain electrode positioned on the second insulation layer, and coupled to the source region and the drain region, respectively; and

a third insulation layer positioned on the source electrode and the drain electrode and having a via hole exposing one of the source electrode and the drain electrode;

18

wherein the first electrode is positioned on the third insulation layer and coupled to the exposed one of the source electrode and the drain electrode through the via hole, and the first color modulation layer is positioned between the first electrode and the substrate.

28. The organic light-emitting device of claim 27, wherein the first color modulation layer is positioned in at least one place of a place between the first electrode and the third insulation layer, a place between the third insulation layer and the second insulation layer, a place between the second insulation layer and the first insulation layer, and a place between the first insulation layer and the substrate.

29. The organic light-emitting device of claim 28, further comprising a first overcoating layer interposed between the first electrode and the first color modulation layer, when the first color modulation layer is positioned between the first electrode and the third insulation layer.

30. The organic light-emitting device of claim 1, wherein the first electrode is an anode and the second electrode is a cathode.

31. The organic light-emitting device of claim 1, wherein the first electrode is a cathode and the second electrode is an anode.

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